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2d, The manner in which polygamy may have originated.

3d, The origin and effect of excessive pugnacity.

4th, The origin and advantage of great sexual disparity.

5th, The origin and advantage of the ability to endure long-protracted fasts.

The sexual disparity, excessive pugnacity, and ability to endure protracted fasts are all intimately related to polygamy, either as cause or effect.

Up to a certain point pugnacity and disparity seem to have acted as causes of polygamy. Beyond that point they seem to be effects of polygamy, or at least are accelerated or intensified by it.

The ability to endure long fasts would seem to be purely an effect of polygamy.

ON THE GENESIS OF THE CHROMATOPHORES IN FISHES.[1]

BY CARL H. EIGENMANN.

FOR several reasons pelagic eggs are more available for a study of the phenomena of color-formation than fixed eggs. Pigment is nearly always formed in pelagic eggs some time before hatching, and as the embryonic life is usually short and the eggs are transparent, the whole process from fertilization to hatching can be observed, without any great inconvenience, in the living egg.

In all pelagic ova with oil-globules observed by me pigment is deposited in certain cells before the time of hatching. In the eggs of three species of pelagic ova (Stolephorus) without oil-globules no pigment is formed several hours after hatching, while in *Fierasfer dubius* (?) without oil-globules, pigment is present at the time of hatching.

Only three colors have been observed in the eggs examined, viz., black, a brownish-yellow, and bright yellow. In the various species of Sebastodes (viviparous) only black pigment is formed, while in Atherinopsis black pigment alone is observed until near

[1] Notes from the San Diego Biological Laboratory, IV.

the time of hatching, when bright yellow pigment appears. In the pelagic ova observed, excepting Stolephorus, black pigment was always formed, but never in great quantity. In *Serranus nebulifer* (Fig. 34) only black pigment is formed before hatching, while in *Serranus maculofasciatus*, *Sciæna saturna*, and *Hypsopsetta guttulata* the few black cells are almost obscured by the great number of brownish-yellow cells. In those cases in which both black and yellow cells appear the black cells soon collect on the lower surface of the oil-globule and on the lower surface or back of the embryo, while the yellow cells are aggregated on top of the oil-sphere and on the ventral surface of the embryo,—a fact already observed by others.

Figs. 32 to 41 will give a fair idea of some of the various patterns the color-cells form in early stages. Figs. 33 to 40 represent nearly homologous stages of various embryos. The time required to reach these stages differs, however, vary greatly in the various species. Figs. 33, 34, and 40 represent larvæ between two and three days old, while Figs. 35 to 39 represent larvæ as many, or more, weeks old. The conditions of development also vary greatly in the larvæ selected for illustration. Figs. 33, 34, and 40 are all hatched from pelagic ova; Fig. 36 from ova which adhere together and are thus hatched in masses; Fig. 38 from ova with a mycropylar circlet of filaments; and Fig. 39 from ova with isolated filaments scattered over the entire zona; while Fig. 37 represents a viviparous fish just at the time of birth.

Viviparity does not affect the chromatophores immediately. In the rock cod (Sebastodes), Fig. 37, color is as well formed at the time of parturition as in some related viviparous species. In the Holconotidæ, on the other hand, color is not formed until quite late stages are reached, and the eyes are the first to be pigmented.

In all cases observed the chromatoblasts originate in the mesoblast surrounding the embryo. This condition was considerably modified in *Sciæna saturna*, in which they are formed along the entire margin of the embryonic ring; but the difference is one of degree only.

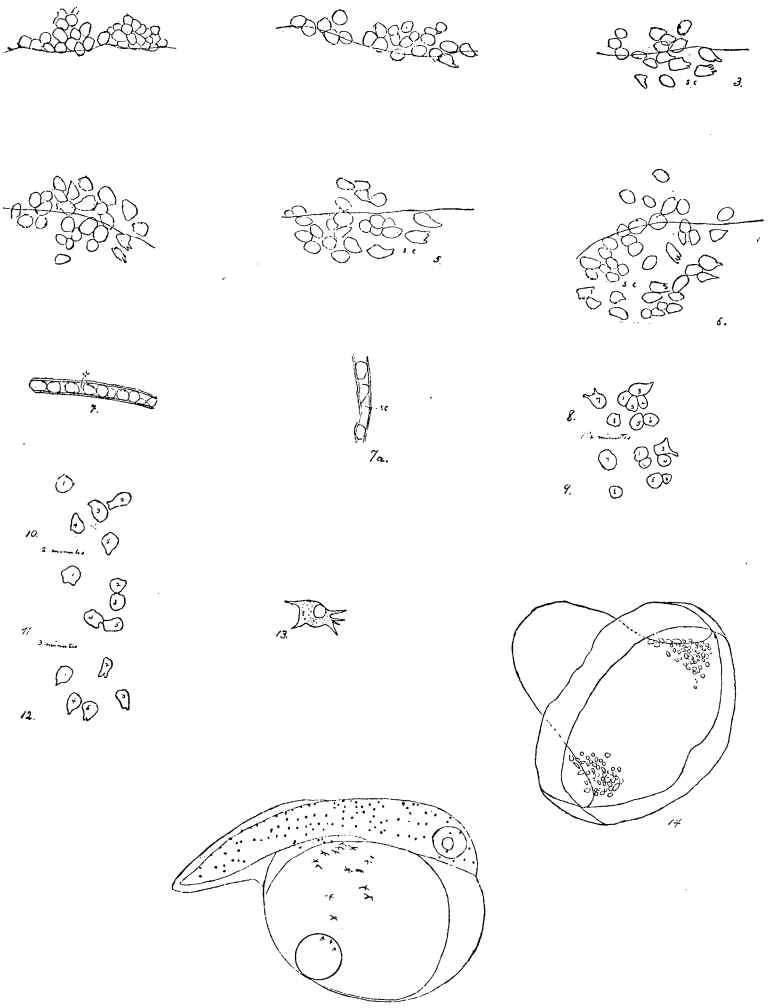
To follow the species observed separately:

In *Sciæna saturna* (Figs. 1–7) the chromatoblasts are first noticed when the gastrula covers about one-third of the yolk; that is, they appear quite early. They are formed along the entire margin of the embryonic ring. When first noticed they are slightly separated from the surrounding cells, and their outlines become well defined. They thus appear larger than the cells surrounding them, which are closely packed and whose outlines are not sharply defined. They either move toward the outer rim of the embryonic ring or remain stationary, while the embryonic ring moves over the yolk. At any rate, they soon come to lie entirely in the segmentation cavity, (see Figs. 1–7). At this time they are quite regular in outline, with probably one or two angular prolongations. Their depth is usually equal to that of the segmentation cavity, and much greater than the epiblast below them or the ectoderm above them. As soon as they have reached the segmentation cavity they migrate in it, most of them being intended for the embryo, while many remain on the yolk, and others cover the oil-globule.

While the individual cells undergo amœboid changes, their locomotion is not necessarily caused, as some observers supposed, by their amœboid changes. One cell, which was smaller than usual, was seen to move quite rapidly towards the oil-globule, with a motion not unlike that of ciliate Infusorians caught under a cover-glass; *i. e.*, it moved quite rapidly, and then seemed to be momentarily arrested by some invisible barrier, when it would again dart along. When the cells are first freed from the embryonic ring no color is seen in them; but before long fine granules are observed, resembling in most respects the minute oil-globules covering the yolk. Individually these are apparently colorless, but collectively they form yellow or black pigment. On the oil-globule and embryo, and later over the yolk also, the cells become flattened, more densely pigmented, and at the same time gain the power of contracting the pigment to a dot (Fig. 15), or expanding it to the dendritic form of the cell itself (Fig. 17).

I have not observed any other cells than the migratory ones in this species; if others exist, they were obscured by the large

PLATE III.



EMBRYOS OF FISHES.

quantities of migratory cells. I have not had an opportunity of reëxamining this species or Hypsopsetta since the species of *Serranus* were observed.

In *Hypsopsetta guttulata* the color-cells appear much later and not nearly in such large quantities as in Sciæna. They are first noticed when the gastrula covers only one-half or two-thirds of the yolk, and the migratory ones are formed only at or near the union of the embryonic shield and the embryonic ring (Fig. 14). Numerous cells are soon after seen along the entire embryo. I am not certain whether they originate *in situ* or whether they migrate to their position. Later, when the embryonic shield is contracted to form the embryo, these cells move toward it, and finally cover it. Later other cells again move out from the embryo to cover the yolk (see Figs. 15–17).

The observations on *Serranus nebulifer* (Fig. 34) were not very complete. Only black cells are formed, and very few cells become free from the embryo, all of which migrate to the oil-sphere.

In *Serranus maculofasciatus* (Figs. 18–28) the chromatoblasts were observed about sixteen hours after fertilization. There were at that time a few free ones on either side of the embryonic shields. In fifteen minutes the number of free ones on one side had increased from nine to fifteen (see Figs. 18–22). These cells moved rapidly away from their place of origin, and most of them finally, in about two hours and a half, were found on the oil-sphere. A few probably returned, and finally lodged in the region of the head. Besides these migratory cells, there is a broad band of mesoblastic cells along either side of the embryo in which color is soon formed. These cells never become nomadic in the segmentation cavity, but remain attached to the embryo, over which they are finally nearly evenly distributed. By far the greater portion are yellow cells, but a few being black. Before hatching these cells become collected into definite masses, and some time after hatching they assume the remarkable condition observed in Fig. 33.

So far as I am aware, nothing has been written concerning the origin of the color itself. As stated above, the color is not due to the color of the protoplasm of the chromatophores but to the aggregation of small granules, most probably oil-spherules. The

protoplasm is colorless. The color-granules are not found in the nucleus of the cells. They are sometimes scattered through the whole of the remainder of the cell, but can be withdrawn from the pseudopods of the adult chromatophore and collected in a small spot. It is to the ability on the part of the chromatophores to thus distribute or collect the color-granules that the larva owes its power to rapidly change color.

The individual spherule of the chromatophores does not possess any definite color. It is only, as has been stated, when a number of them are aggregated that color is evident. These granules are either a secretion of the cell itself, or they are formed otherwise and appropriated by the cell. The process of the formation of the granules in the chromatophores would, of course, be difficult to follow if they were secreted by the cell. On examining the medium surrounding the migratory cells for a possible explanation of the color-spherules, it was found that the epiblast was full of granules or oil-spherules, similar in size and but slightly, if any, different in refractive index. Such spherules were especially abundant in Sciæna, in which there is also an unusual number of color-cells. Especially towards the closing of the blastopore, a large number are seen over the entire portion of the yolk not covered by the gastrula, and it seems as though the advancing embryonic ring were heaping them up at the entodermic pole of the egg.

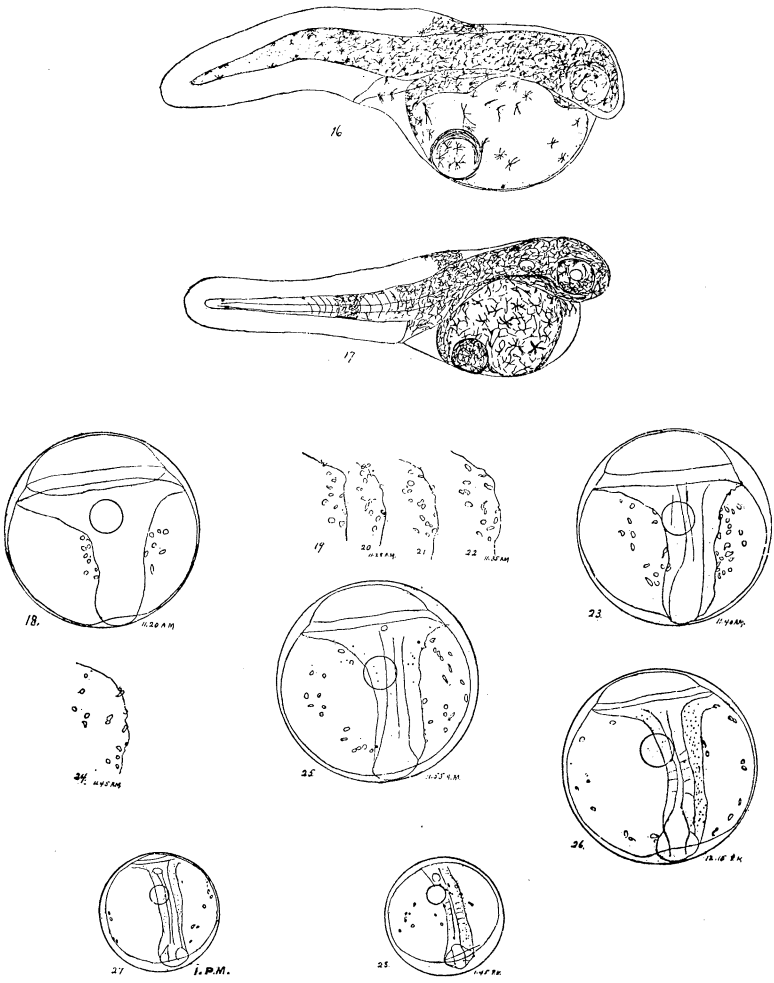
I have frequently observed individual chromatophores while in the segmentation cavity, and have seen them put forth pseudopods and withdraw them independently of their locomotion; but I have never seen them in the act of appropriating any of the spherules of the epiblast.

There is a difference between the spherules of the yellow and of the black cells. The granules of the black cells are smaller and less refringent.

When first freed from the embryonic ring the color-cells usually approach the typical cell in shape, but later they become flattened and assume the dendritic form so characteristic in the larvæ.

These observations were made while at a distance from all scientific libraries. After they had been prepared for the printer,

PLATE IV.



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I was enabled, through the courtesy of Dr. C. O. Whitman, to examine the records of previous observations during my stay at the Marine Biological Laboratory at Woods Holl. Although I then found that many of my observations were but verifications of those of others, it has seemed best to publish my account because I have examined new material, have worked out the matter in greater detail in several species, and do not agree with the previous observers in all points.

Aubert,[2] Kupffer,[3] Agassiz and Whitman,[4] Wenkebach,[5] and List [6] all seem to agree in deriving the chromatophores from the mesoblast; as to when and where they arise these authors naturally vary with the different species examined.

All the figures, excepting 37, were made from living eggs or larvæ, with a Zeiss microscope and Abbe camera. The letters A and D refer to the objectives, the 2 and 4 to the oculars, of Ziess.

EXPLANATION OF PLATES.

PLATE I.—*Sciæna saturna.* Figs. 1–6, a portion of the embryonic ring, showing the chromatophores. In Fig. 1 they are all still contained in the embryonic ring. In Fig. 2 a few are seen entering the segmentation cavity. Figs. 3 and 4 show a portion only of the region covered by Figs. 1 and 2, with more cells in the segmentation cavity, Fig. 4 being drawn five minutes later than Fig. 2. Figs. 5 and 7 show still later stages, in which a still larger number of cells have been freed; Zeiss, D and 4. Fig. 7, an optical section of the segmentation cavity (s. c.), near the embryonic ring, showing the large chromatophores, the thin ectoderm lying above them, and the parablast below them. Fig. 7*a*, the same at some distance from the embryonic ring, the chromatophores being much less numerous. Fig. 8, a series of eight free chromatophores of *Hypsopsetta guttulata;* D and 4. Fig. 9, the same cells 1½ minutes later. Fig. 10, a series of five chromatophores. Fig.

[2] Beiträge zur Entwickelungsgeschichte der Fische. *Zeitschr. f. wissensch. Zool.*, VII., 1856.

[3] Beobachtungen über die Entwickelung der Knochenfische. *Arch f. mikr. Anat.*, IV., 1868.

[4] The Pelagic Stages of Young Fishes. Mem. Mus. Comp. Zool., pp. 7 and 40, 1885.

[5] Beiträge zur Entwickelungsgeschichte der Knochenfische. *Arch. f. mikr. Anat.*, XXVIII., 1886.

[6] Zur Entwickelung der Knochenfischen (Labriden). *Zeitschr. f. wissensch. Zool.*, XVL., 1887.

11, the same two minutes later. Fig. 12, the same three minutes later than Fig 11. Fig. 13, a single chromatophore, more highly magnified after pigment has begun to be formed. Fig. 14, outline of embryonic shield and ring, with chromatophores beginning to be freed; A and 4. Fig. 15, a larva just freed from the membrane, 1.4 mm.; the chromatophores contracted.

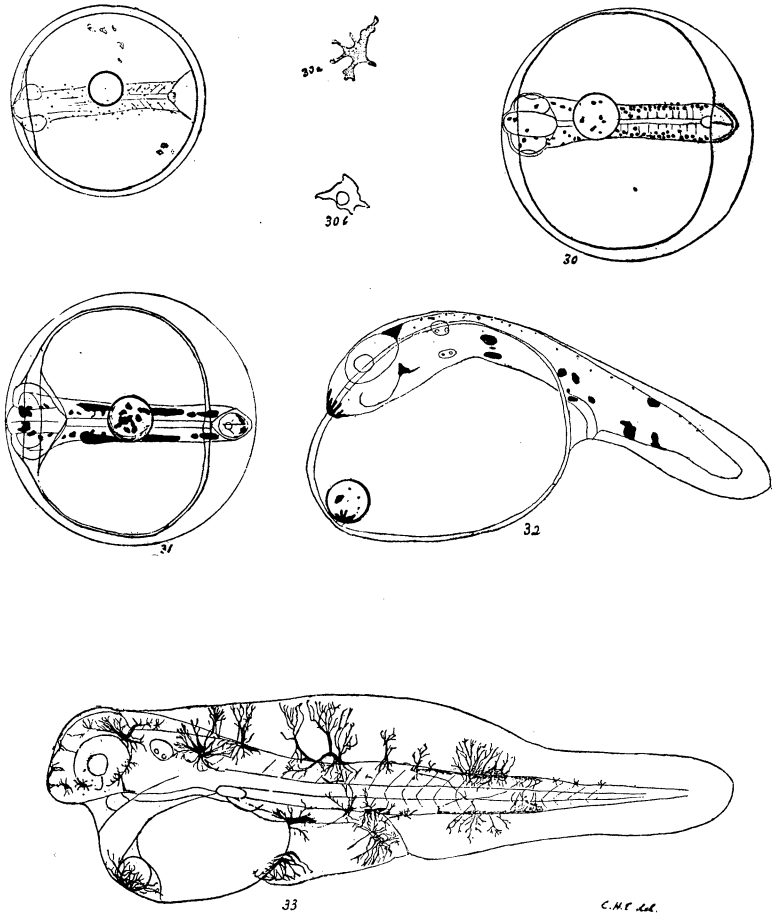
PLATE II.—The same larva (Fig. 15) twenty hours afterwards, 1.6 mm. Fig. 17, another more advanced larva, 1.7 mm. long.

Serranus maculofasciatus.—The aim being to show the chromatophores, the details of the embryo were not as well attended to as they otherwise would have been. Figs. 18–28 represent the successive positions of the free chromatophores from the time they become free till they have nearly reached the oil-sphere. The exact times when the drawings were made are indicated with the figures. The egg figured was probably fertilized at about 5 P.M. the day preceding the stages represented. Figs. 19–22 and 24 show merely one side of the embryonic shield. In Fig. 25 the lateral cells have begun to be pigmented Figs. 18–26, Zeiss, A and 4; Figs. 27, 28, A and 2.

PLATE III.—Fig. 29, slightly older egg than Fig. 28; A and 4. Fig. 30, the free chromatophores have reached the oil-sphere, the yellow cells lying on the upper surface, the black on the lower surface; the chromatophores of the body have become more densely pigmented; A and 4. Fig. 30*a*, a chromatophore (the nucleus is not seen), with the color-granules from the oil-sphere of Fig. 30; D and 4. Fig. 30*b*, another chromatophore, showing nucleus, also from oil-sphere of Fig. 30; D and 4. Fig. 31, a later stage, the yellow cells having aggregated in large masses; A and 4. Fig. 32, immediately after hatching, the yellow cells being large, the black cells small, all the cells contracted; A and 4. Fig. 33, twelve hours after hatching, the cells expanded to their utmost and constantly changing; A and 4, 2.2 mm.

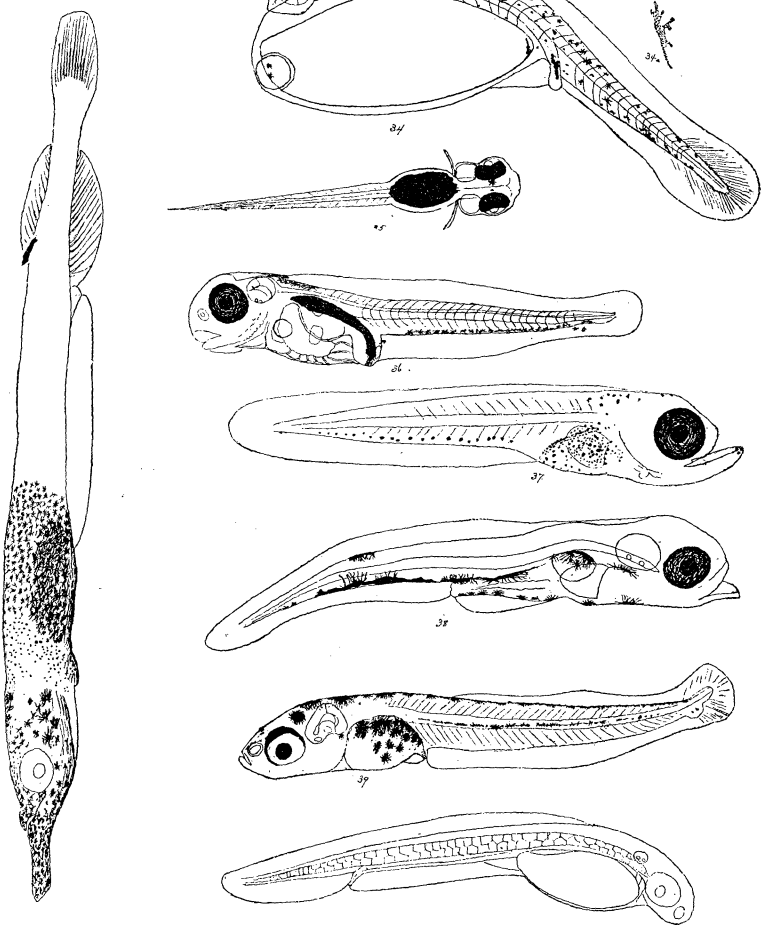
PLATE IV.—Fig. 34, a newly hatched larva of *Serranus nebulifer;* 2.67 mm. Fig. 34*a*, one of the chromatophores from the tail, more enlarged; D and 4. Fig. 35, *Oligocottus analis*, twelve hours after hatching; dorsal surface; X 25. Fig. 36, somewhat older *Oligocottus analis*, two days after hatching; lateral view; X 35. Fig. 37, *Sebastodes ruber*, at the time the larvæ are freed from the ovary. This is probably a pathological specimen; the tail is usually more elongate. Fig. 38, Lepidogobius sp., showing peculiar distribution of pigment; X 68. Fig. 39, *Atherinopsis californiensis*, after the yolk is all absorbed; Jan 9, 1889; X 12. Fig. 40, *Stolephorus ringens*, forty-eight hours after hatching; no color is formed in the latest stages observed. Fig. 41, *Hemisbamphus rosæ*, 12.5 mm. long, showing the distribution of the color cells; the cells of the posterior part of the body and of the tail are omitted.

PLATE V.



EMBRYOS OF FISHES.

PLATE VI.



EMBRYOS OF FISHES.